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Supporting Information

Imitating micelles as a way to control coordination self-assembly: cage versus polymer directed rationally by solvent polarity or pH

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Experimental Section

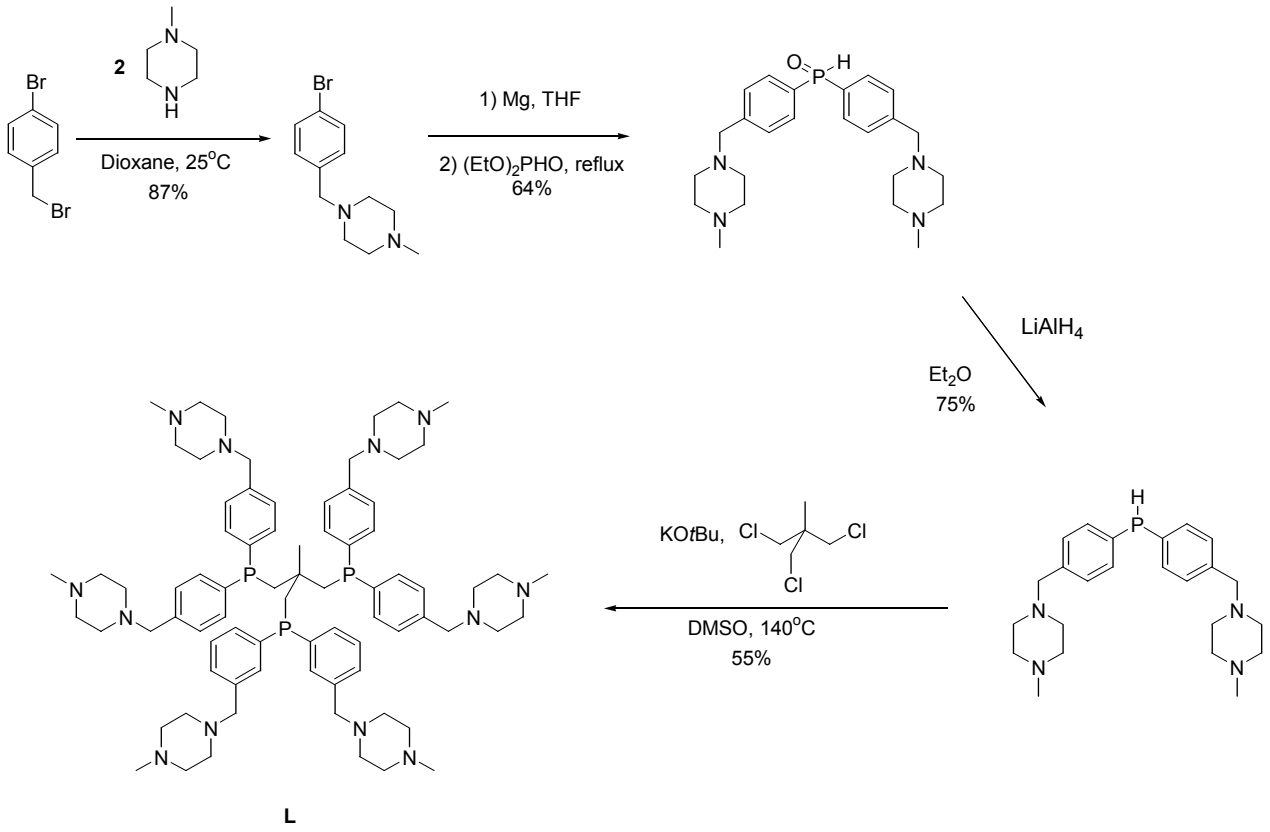
General. All reactions requiring anhydrous or inert conditions were carried out under an inert atmosphere of dry nitrogen using standard Schlenk line techniques.

Solvents and materials. Tetrahydrofuran and diethyl ether were distilled under nitrogen from sodium benzophenone ketyl. All other solvents and reagents were used as received from commercial suppliers. Chemicals were purchased from Sigma-Aldrich Chemical Company. Solvents for extractions or cromatography were of technical grade. Flash-chromatography was carried out using Merck Silica (40-60 μ). Analytical TLC was performed with Merck Silica gel 60 F_{254} plates..

Product analysis. Electrospray mass spectra were carried out on the Waters LCT Premier™ XE benchtop orthogonal acceleration time-of-flight (oa-TOF) mass spectrometer.^{1}H, ^{13}C, ^{31}P and 2D (P-COSY) NMR spectra were all recorded on Bruker AM 300 MHz or AM 500 MHz referenced to the residual ^{1}H or ^{13}C containing solvent or to external 85% H_3PO_4 in the case of ^{31}P-NMR. Chemical shifts (δ) are given in parts per million (ppm) and coupling constants are given in Hertz. Elemental analysis were determined by the Analytical Service Department of the School of Chemistry (ASEP) using a Perkin-Elmer 2400 CHN microanalyser. A commercial Malvern Zeta-Nano Sizer was used for DLS measurements. The size distribution calculated by the Nano software is derived from a non-negative least squares (NNLS) analysis. The instrument was periodically verified by measuring polystirene latex standards from Duke Scientific Corporation. To avoid any possible dust contamination during preparation of the solutions, the dispersants were filtered using syringe filters with pore size of 200 nm. Three repeat measurements were performed on the same sample to check count rate repeatability.

CMC measurement by DLS and dye inclusion. The critical micelle concentration (CMC) was measured by DLS, by analyzing size and count rate for samples at different concentrations of **L** (from 0 to 10^{-2} M) and confirmed by using the colorimetric technique based on the oil-soluble dye, 1-(2-pyridylazo)-2-naphthol (PAN). 100 ml of a saturated solution of PAN in pentane (~ 1.6 x 10^{-3} M) was prepared. A set of 10 solutions of **L** at various concentrations were made from 0 to 10^{-2} M. 2 drops of the saturated PAN solution in pentane were added to 2 ml of each solution. The solutions were gently

swirled, allowing the pentane to evaporate and the color to develop, and then were filtered. The intensity of the color in each solution was noted and their absorbance measured at 470 nm (ligands absorb at 290 nm).



4-[*N*-(*N*-methylpiperazinyl)methyl]bromobenzene: Bromobenzylbromide (80.0 mmol) was dissolved in 50.0 ml of dioxane and 4-methylpiperazine (17.7 ml, 160.0 mmol) was slowly added at 0°C. After stirring for one hour, the 4-methylpiperazinium bromide was filtered off, the solution diluted with 200 ml of diethylether, washed with brine and water and dried over sodium sulfate. Evaporation of the solvent under vacuum gave the pure product as yellow oil. Yield : 18.8g (87 %). ^{1}H-NMR (300 MHz, $CDCl_3$) δ 7.39 (d, 2H, $^{3}J_{HH}$ = 9 Hz), 7.17 (d, 2H, $^{3}J_{HH}$ = 9 Hz), 3.42 (s, 2H), 2.42 (bs, 8H), 2.25 (s, 3H). ^{13}C-NMR (75 MHz, $CDCl_3$)): δ 137.8, 131.7, 131.2, 121.2, 62.7, 55.5, 53.5, 46.5. ES-MS (m/z): 269 $(M+H)^+$.

***Bis*{4-[*N*-(*N*-methylpiperazinyl)methyl]phenyl}phosphine oxide:** To a solution of 4-[*N*-(*N*-methylpiperazinyl)methyl]bromobenzene (30.0 mmol) in dry THF, Mg (0.9 g, 36.0 mmol) and a crystal

of iodine were added at 0°C. After the exothermic reaction had taken place, the mixture was stirred at r.t. for 1 hour. Diethyl phosphite (1.3 ml, 9.9 mmol) was then added at r.t. and the mixture heated to reflux for 2 hours. The reaction was quenched with water (100 ml) and the milky mixture was filtered through a short pad of Celite in order to remove the magnesium hydroxide gel. The pad was washed with chloroform. The water phase was extracted with chloroform (3 x 100 ml) and the collected organic phases dried over Na_2SO_4 and concentrated under reduced pressure. The mixture obtained was purified by flash-column chromatography (DCM / MeOH 95/5 + 1% ammonia 35% solution) to yield the product as a yellow oil. Yield = 1.7g (41 %).^{1}H NMR (300 MHz, $CDCl_3$) δ 8.04 (d, 1H, $^{1}J_{HP}$ = 479 Hz), 7.63 (dd, 4H,$^{3}J_{HH}$ = 8 Hz, $^{3}J_{HP}$ = 13 Hz,), 7.45 (dd, 4H, $^{3}J_{HH}$ = 8.0 Hz, $^{4}J_{HP}$ = 2 Hz), 3.54 (s, 4 H), 2.44 (bs, 16 H), 2.27 (s, 6 H).^{31}P-{^{1}H} NMR (121 MHz, $CDCl_3$) δ 22.4.^{13}C NMR (75 MHz, $CDCl_3$) δ 143.8 (d,$^{4}J_{CP}$ = 2 Hz), 131.0 (d, $^{3}J_{CP}$= 12 Hz), 130.1 130.5 (d, $^{1}J_{CP}$ = 102 Hz), 129.9 (d, $^{2}J_{CP}$ = 13 Hz), 62.8, 55.3, 53.3, 46.2. ES-MS (m/z): 427 $(M+H)^+$.CHN analysis for $C_{24}H_{35}N_4OP$: C, 67.58, H, 8.27, N, 13.14; found C, 66.98, H, 8.67, N, 12.74.

1,1,1-*tris*{*bis*[4-(*N*-(*N*-methylpiperazinyl)methyl)phenyl]phosphinomethyl}ethane (L): To a suspension of *bis*{4-[*N*-(*N*-methylpiperazinyl)methyl]phenyl}phosphine oxide (3.5 mmol) in diethyl ether (150 ml), was added an excess of lithium aluminium hydride (0.5 g, 14.0 mmol) in small portions and the reaction stirred overnight. Distilled degassed water (10 ml) was added slowly, cooling with an ice-bath, to produce a white suspension. The organic layer is transferred to another flask via a canula. The diethyl ether was removed *in vacuo* affording *bis*{4-[*N*-(*N*-methylpiperazinyl)methyl]phenyl}phosphine as a colourless oil.Yield = 0.93g (65 %). ^{31}P-{^{1}H} NMR (121 MHz, $CDCl_3$) δ -45.5 (s). To bis-{4-[*N*-(*N*-methylpiperazinyl)methyl]phenyl}phosphine (1.60 g, 3.82 mmol) in DMSO (4 ml), potassium *tert*-butoxide (0.43 g, 3.85 mmol) was added at r.t. producing an intense dark-red solution. After stirring for 15 min , 1,3-dichloro-2-(chloromethyl)-2-methylpropane (0.16 ml, 1.15 mmol) was slowly added and the mixture heated at 130°-140°C for 4 h. Distilled water (2ml) was added to quench the reaction and the DMSO was distilled under vacuum. The residue was dissolved in chloroform and dried over Na_2SO_4. The oil obtained was purified by flash-column

chromatography (DCM 95/MeOH 5 + 1% ammonia 35% solution) affording a white solid. Yield = 0.20 g (51%). M.p. = 115°-120°C. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.27 (dd, 12H, $^{3}J_{HH}$ = 9 Hz, $^{3}J_{HP}$ = 9 Hz), 7.19 (d, 12H, $^{3}J_{HH}$ = 9 Hz), 3.45 (s, 12H), 2.42 (bs, 54H), 2.26 (s, 18H), 0.88 (s, 3H). ^{31}P-{^{1}H} NMR (121 MHz, $CDCl_3$) δ -26.1.^{31}P-{^{1}H} NMR (121 MHz, D_2O) δ -27.0. ^{13}C NMR (75 MHz, $CDCl_3$) δ 138.4, 138.3 (d, $^{3}J_{CP}$=10Hz), 132.9 (d, $^{2}J_{CP}$ = 20 Hz), 129.1 (d, $^{1}J_{CP}$= 8 Hz), 62.7, 55.1, 53.1, 46.0, 43.3-43.1 (m, CH_2), 38.7 (q, $^{2}J_{CP}$ = 13 Hz), 29.2-29.0 (m, CH_3). ES-MS (m/z) : 1298 $(M+H)^+$. CHN analysis for $C_{77}H_{111}N_{12}P_3$: C 71.27, H 8.62, N 12.95; found C 70.65 H 7.92, N 11.74. DLS (20 mM, D_2O, Cumulant Analysis) D_H = 7.0 nm (100 %), PI = 0.07.

$[Ag_6(L1)_4(OTf)_4][OTf]_2$: To a solution of **L1** (0.050 g, 0.038 mmol) in $CDCl_3$ (2 ml), a solution of AgOTf (0.015 mg, 0.057 mmol) in CH_3CN (0.4ml) was added and the mixture stirred for 12 hours. ^{31}P-{^{1}H} NMR (121Hz, $CDCl_3$/CH_3CN=4/1): δ -8.0 (pair of doublets), $^{1}J(^{109}Ag, ^{31}P)$ = 572 Hz.

$[Ag_6(L)_4(OTs)_4][OTs]_2$: To a solution of **L** (0.050 g, 0.038 mmol) in $CDCl_3$ (2 ml), a solution of AgOTs (0.016 mg, 0.057 mmol) in CH_3CN (0.4ml) was added and the mixture stirred for 12 hours. ^{31}P-{^{1}H} NMR (121Hz, $CDCl_3$/CH_3CN=4/1): δ -7.95(pair of doublets), $^{1}J(^{109}Ag, ^{31}P)$ = 570 Hz.

$[Ag_3(L)_2]_n$: To a solution of **L** (0.050 g, 0.038 mmol) in D_2O (2 ml), AgOTf (0.015 g, 0.057 mmol) was added and the mixture stirred for five minutes.^{31}P-{^{1}H} NMR (121Hz, D_2O): δ - 6.9 (broad, $\Delta\nu_{1/2}$ = 900). DLS (D_2O, Intensity size distribution) D_H = 140.0 ± 25 nm.

$[Ag_6(L)_4(OTf)_4][OTf]_2$ in acidified water: To a solution of **L** (0.050 g, 0.038 mmol) in D_2O (2 ml), AgOTf (0.015 g, 0.057 mmol) was added. The mixture stirred for five minutes and trifluoromethansulfonic acid (40 µl) was added dropwise. ^{31}P-{^{1}H} NMR (121Hz, D_2O): δ -5.7 (pair of doublets), $^{1}J(^{109}Ag, ^{31}P)$ = 593 Hz. DLS (5mM, D_2O, Intensity size distribution) D_H = 4.0 ± 0.5 nm. ^{1}H

NMR (300Hz, D_2O): δ 7.54-7.48 (m, 24 H), 7.45 (d, ^3J = 6 Hz, 24 H), 7.16 (d, ^3J = 6 Hz, 24 H), 6.69-6.63 (m, 24 H), 4.37 (bs, 48H), 3.51 (bs, 192 H), 2.89 (s, 72H), 2.56 (s, 12 H), 2.46-2.39 (m, 12 H), 2.29-2.22 (m, 12H).

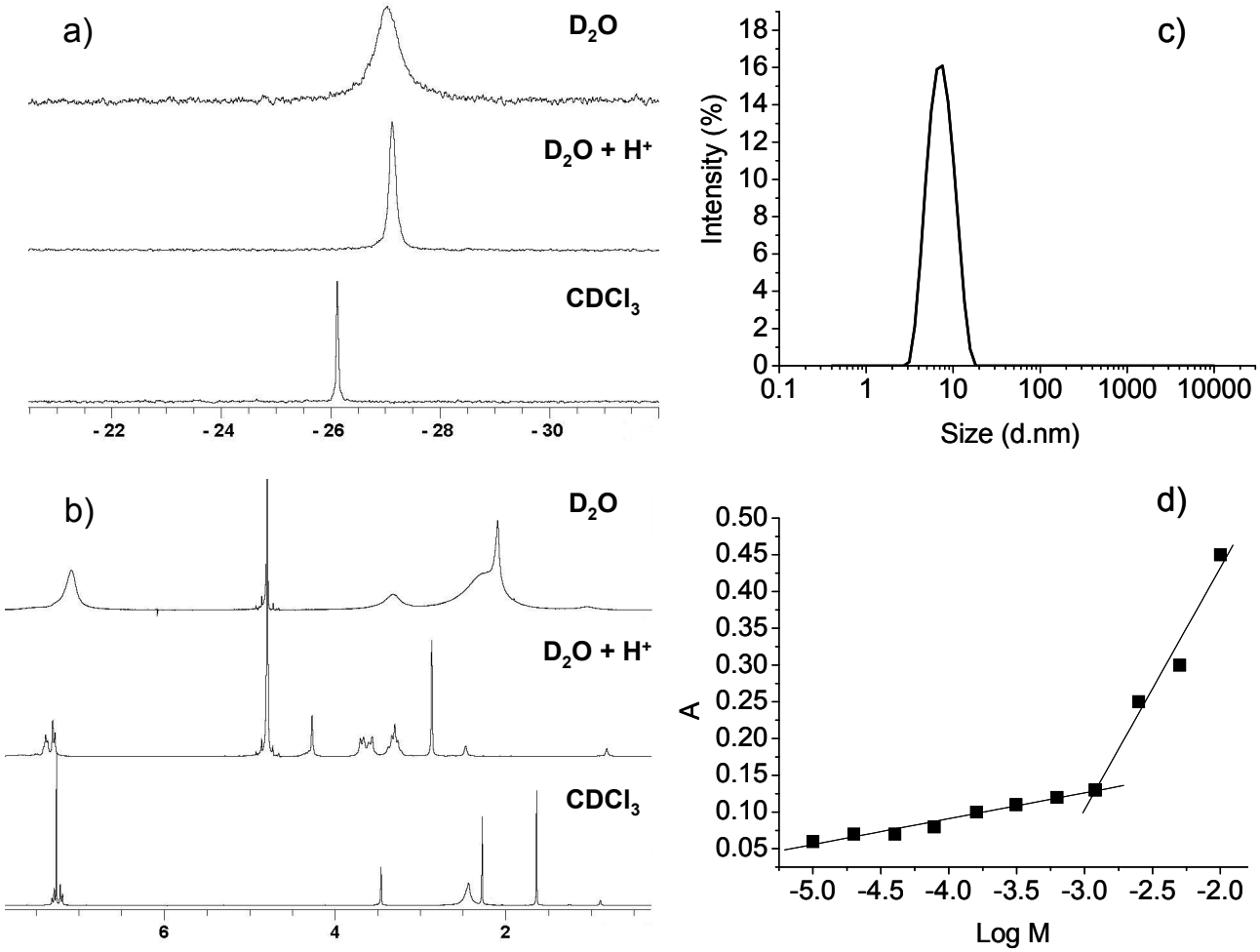


Figure S1 a) ^{31}P NMR spectra of **L** in D_2O, acidified D_2O and $CDCl_3$, b) ^1H NMR spectra of **L** in D_2O, acidified D_2O and $CDCl_3$, c) Dynamic light scattering distribution analysis of **L** in H_2O at 20 mM, d) colorimetric determination of critical micelle concentration (cmc) for **L** in H_2O.

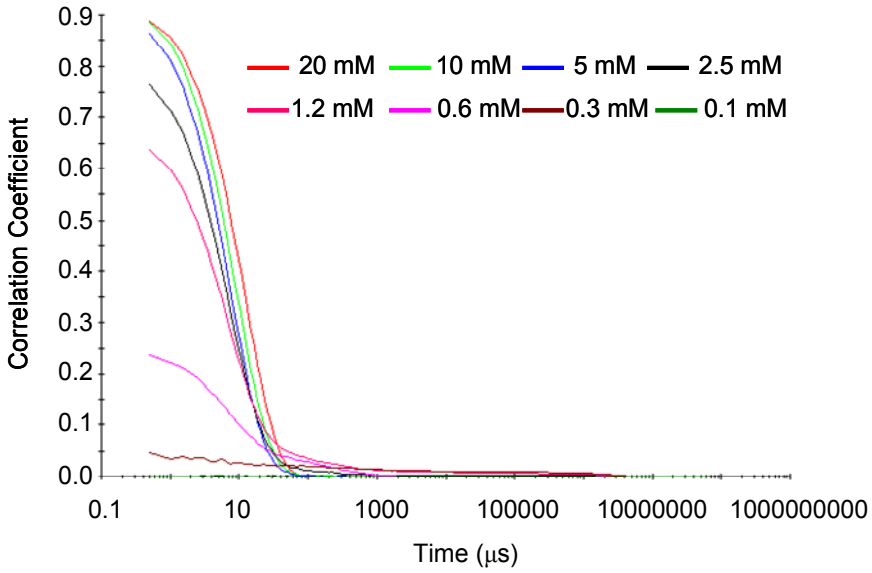


Figure S2 Raw correlation data of aqueous solution of **L** at different concentrations.

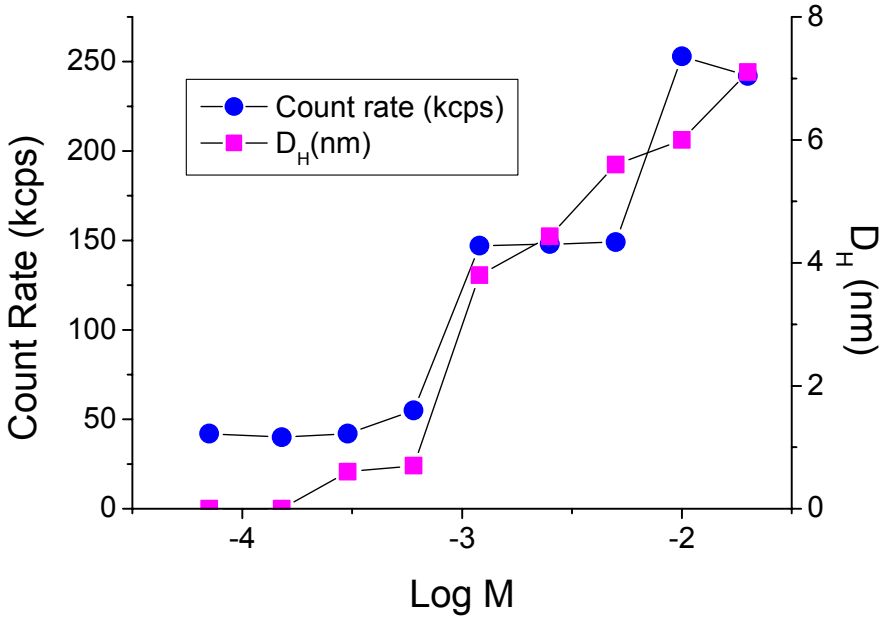


Figure S3 CMC of **L** measured by Dynamic Light Scattering

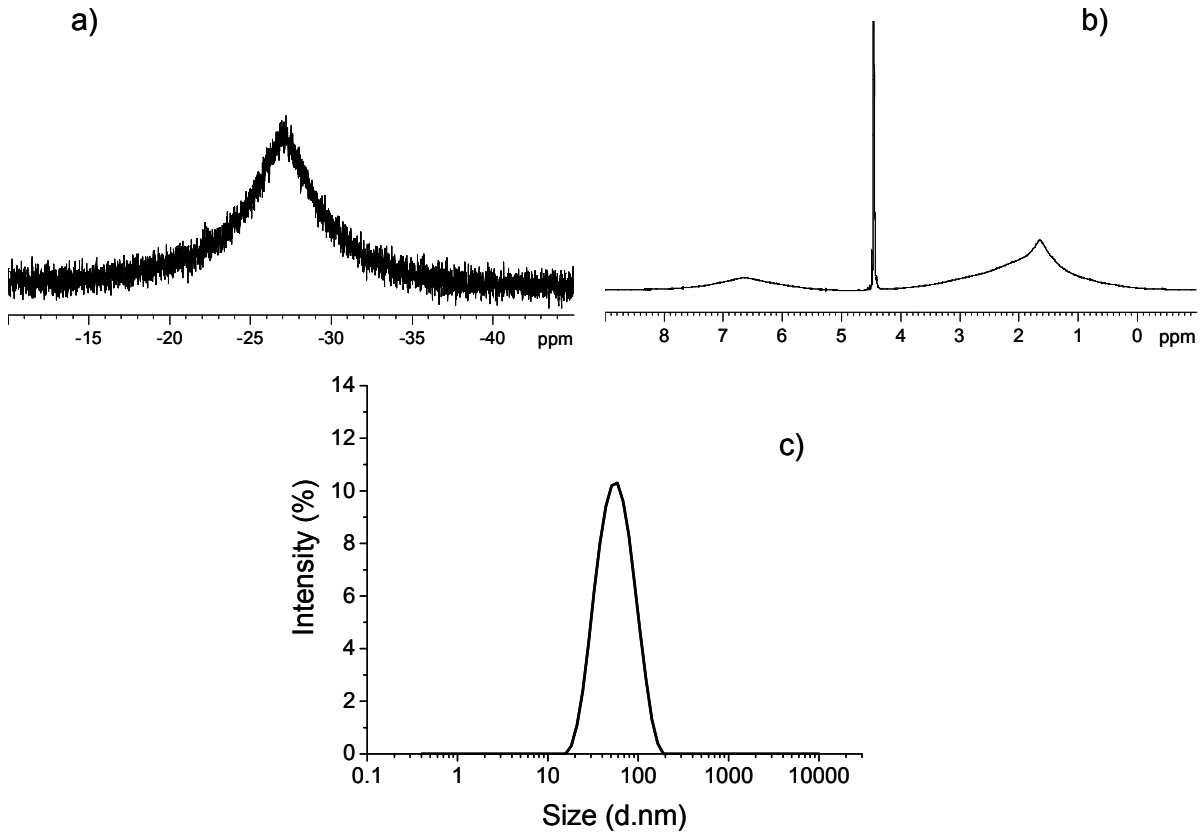


Figure S4 NMR spectra and DLS measurements for free **L** in D_2O or H_2O at high concentration (120 mM) a) ^{31}P NMR spectra of **L**, b) ^{1}H NMR spectra of **L**, c) Dynamic light scattering distribution analysis of **L**.

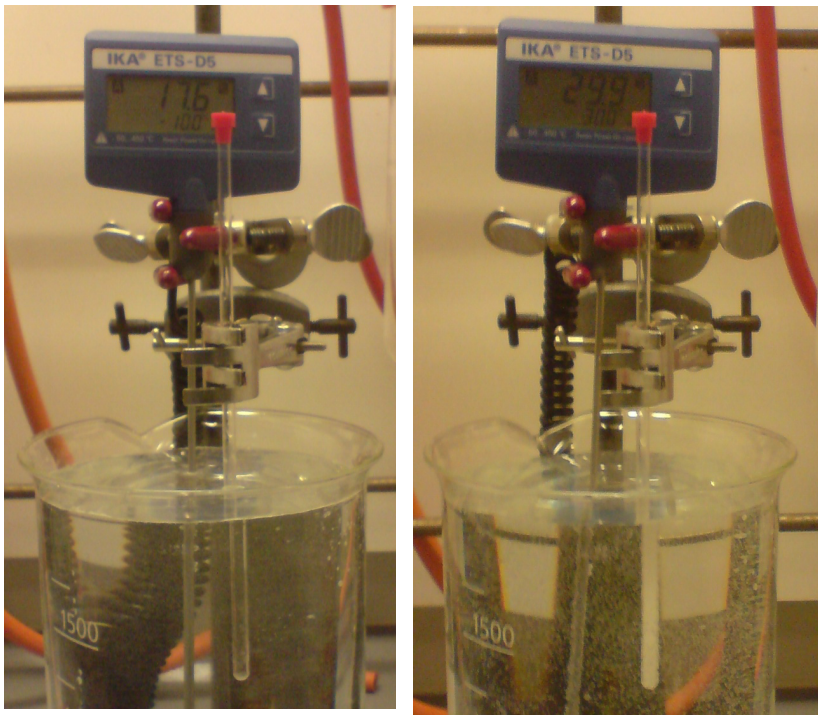


Figure S5 Observation of the cloud point for a 20 mM solution of **L.**.

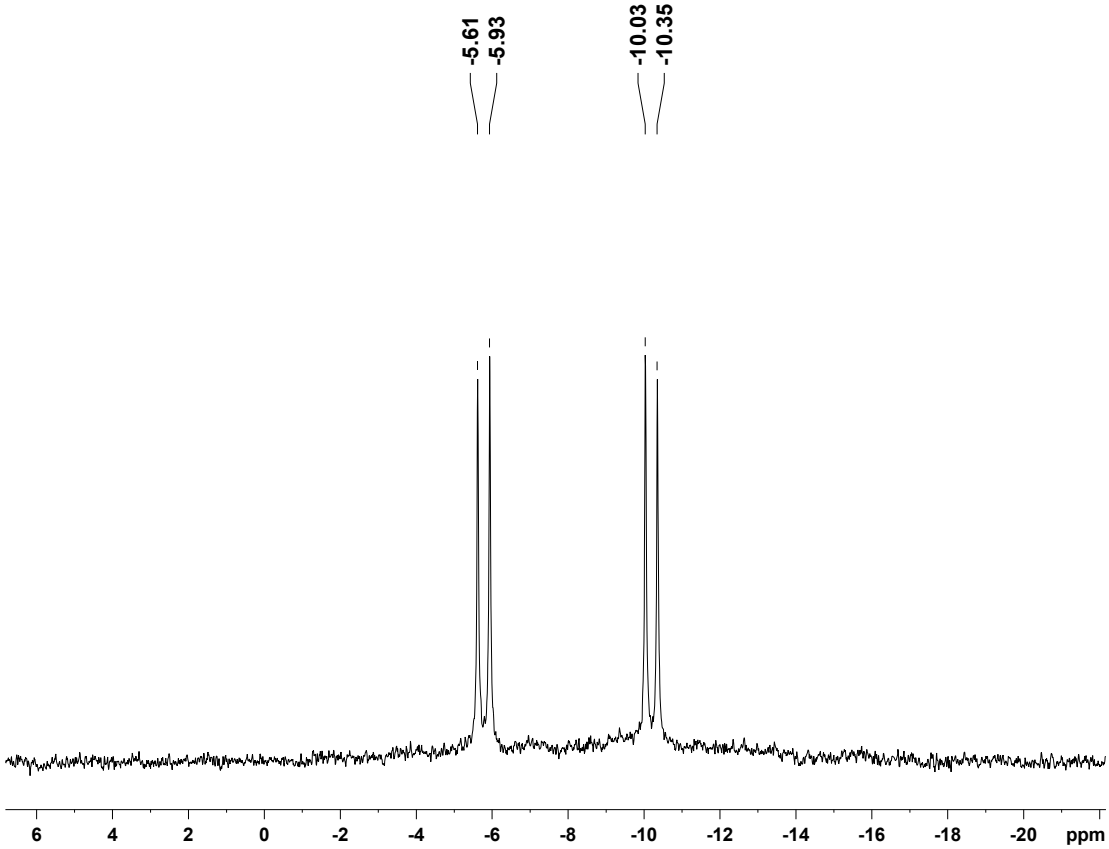


Figure S6 ^{31}P-NMR spectrum of the hexanuclear adamantoid cage $[Ag_6\mathbf{(L)_4}(OTs)_4][OTs]_2$ formed in $CDCl_3/CH_3CN$ = 4/1.

Details of modelling: HyperChem 8.0.3 software was used. The model was constructed starting from crystallographic atomic coordinates for and $[Ag_6\{CH_3C(CH_2PPh_2)_3\}_4(OTf)_4]^{2+}$ obtained from the Cambridge Crystallographic Database (refcode JOXQOC). Para-H atoms were replaced with piperazinyl $CH_2N(CH_2CH_2)_2NCH_3$ substituents which were placed into approximate chair conformations with equatorial substituents prior to energy minimization by molecular mechanics using the AMBER force field. The core atoms (Ag, O, S and $CH_3C(CH_2P)_3$ fragments) were fixed to avoid unrealistic coordination geometries of the triflate anions.